

Small-x and forward measurements at ATLAS

Dag Gillberg
on behalf of the
ATLAS Collaboration

April 11, 2011

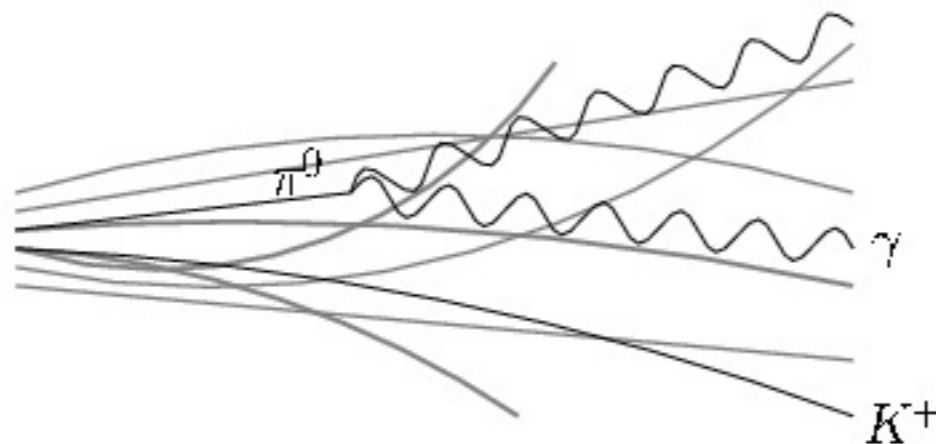
DIS 2011



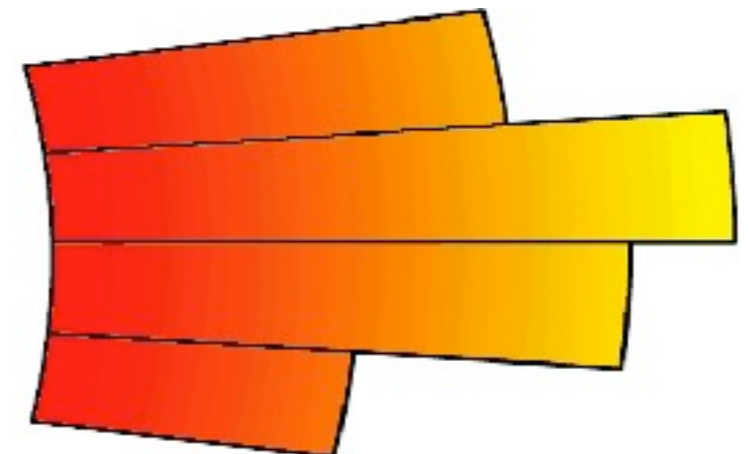
Carleton
UNIVERSITY



parton level jet



particle level jet



calorimeter level jet

Outline

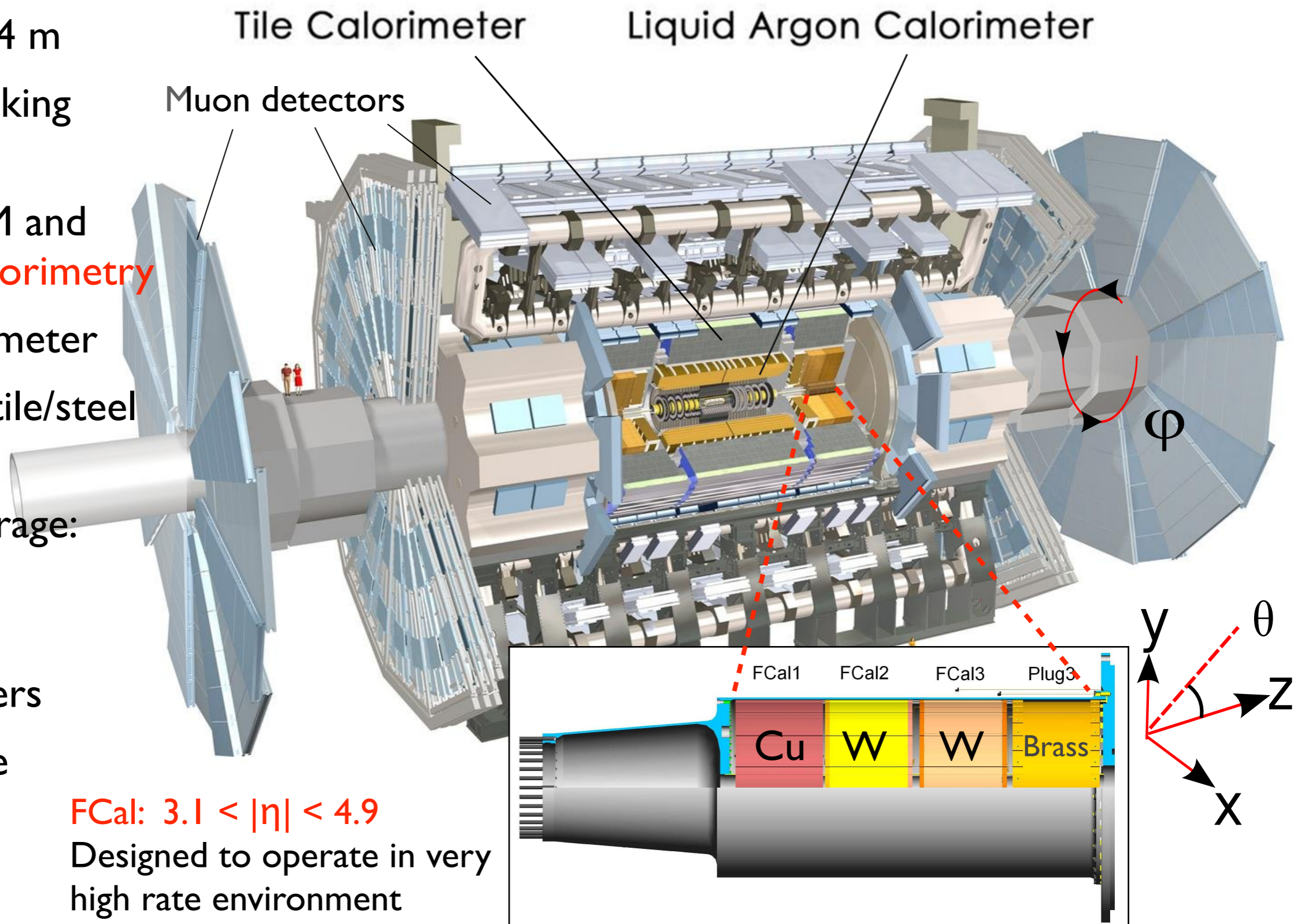
- The ATLAS detector
- Overview of low- x measurements at ATLAS
- Forward jet production and calibration
- Analyses:
 1. Inclusive forward jet cross section measurement
 2. Dijet production with a jet veto
 3. W charge asymmetry
- Summary



Newport News park

The ATLAS Detector

- Length: 44 m
Diameter: 24 m
- Central tracking
 $|\eta| < 2.5$
- Excellent EM and hadronic **calorimetry**
 - LAr calorimeter
 - Hadronic tile/steel scintillator
 - Total coverage:
 $|\eta| < 4.9$
- Muon spectrometers
- Zero-degree calorimeter



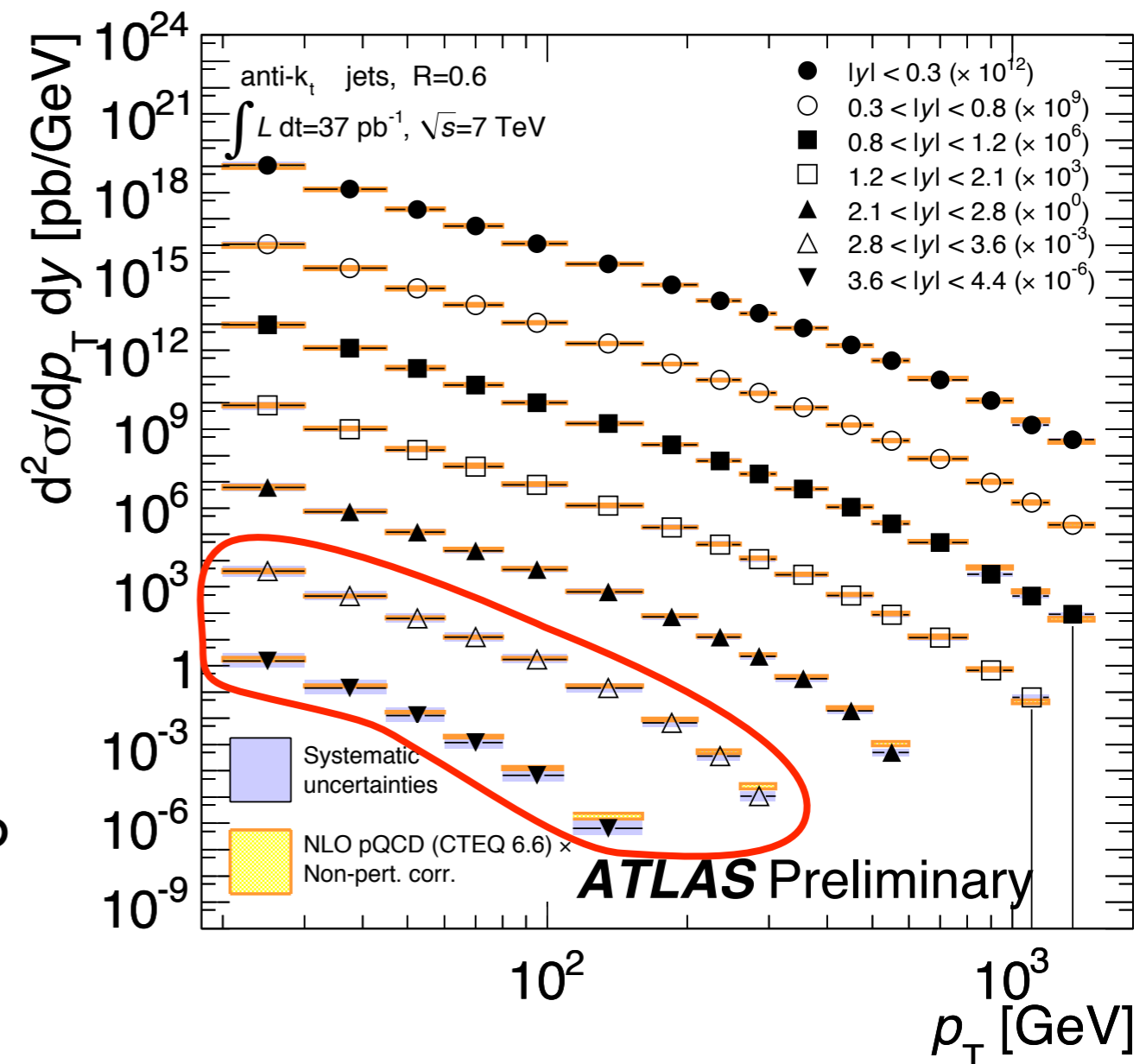
Low-x and forward measurements at ATLAS

Example analyses presented here:

1. **Forward jet inclusive cross section**
(low-x gluon PDF, BFKL)
2. **Rapidity separated jets**
(BFKL and other QCD phenomena)
3. **Muon charge asymmetry from W**
(u and d quark PDFs)

Example of other “small-x” analyses

- Inclusive particle production in pp, Pb+p and Pb+Pb collision data
- Rapidity gaps measurement:
Inclusive diffractive cross section as a function of rapidity gap (in progress)
- Measurement of the underlying event
- Transverse energy flow in the forward region



Inclusive forward jet cross section:
 $2.8 < |y_{\text{jet}}| < 4.4$

Forward jet production

- Consider LO dijet production
- Both jets balanced in transverse plane
- Rapidity separation:
 $\Delta y = |y_1 - y_2| = 2 y^*$
- Parton momentum fraction x given by

$$x_1 = (2p_T / \sqrt{s}) e^{y_{\text{boost}}} \cosh y^*$$

$$x_2 = (2p_T / \sqrt{s}) e^{-y_{\text{boost}}} \cosh y^*$$

- Potential to probe the low- x regime:

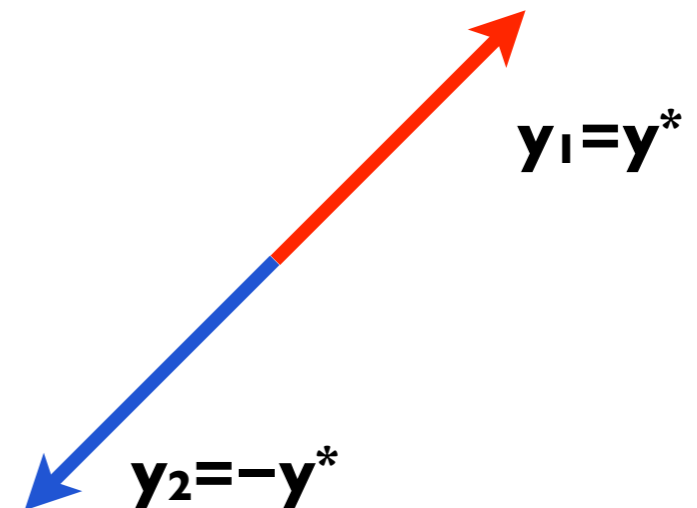
Example:

$$p_T = 20 \text{ GeV}, y_1 = y_2 = 4.0$$

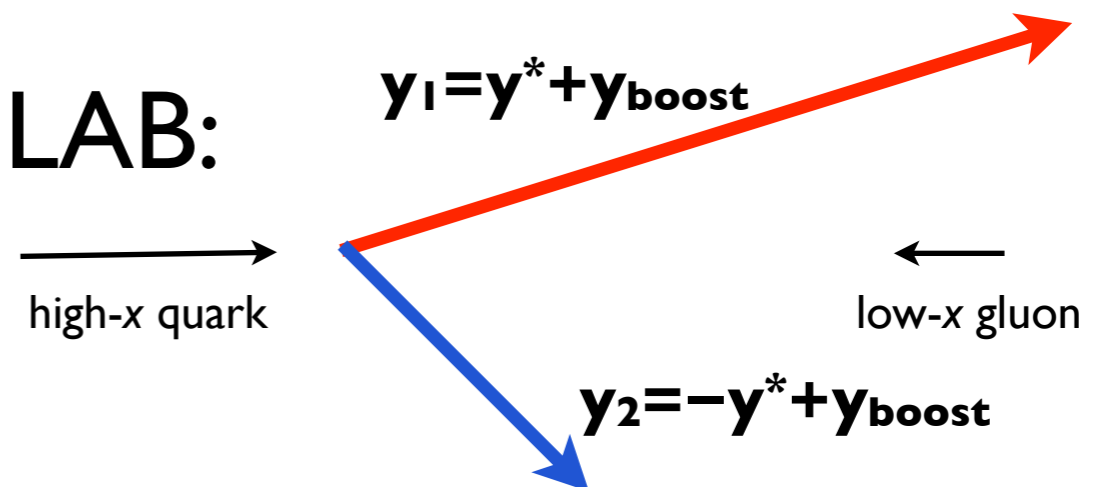
$$\Rightarrow y^* = 0, y_{\text{boost}} = 4.0$$

$$\Rightarrow x_2 \approx 10^{-4} (\sqrt{s} = 7 \text{ TeV})$$

CM:



LAB:



Forward jet production

- Consider LO dijet production
- Both jets balanced in transverse plane
- Rapidity separation:
 $\Delta y = |y_1 - y_2| = 2 y^*$
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$$x_1 = (2p_T / \sqrt{s}) e^{y_{\text{boost}}} \cosh y^*$$

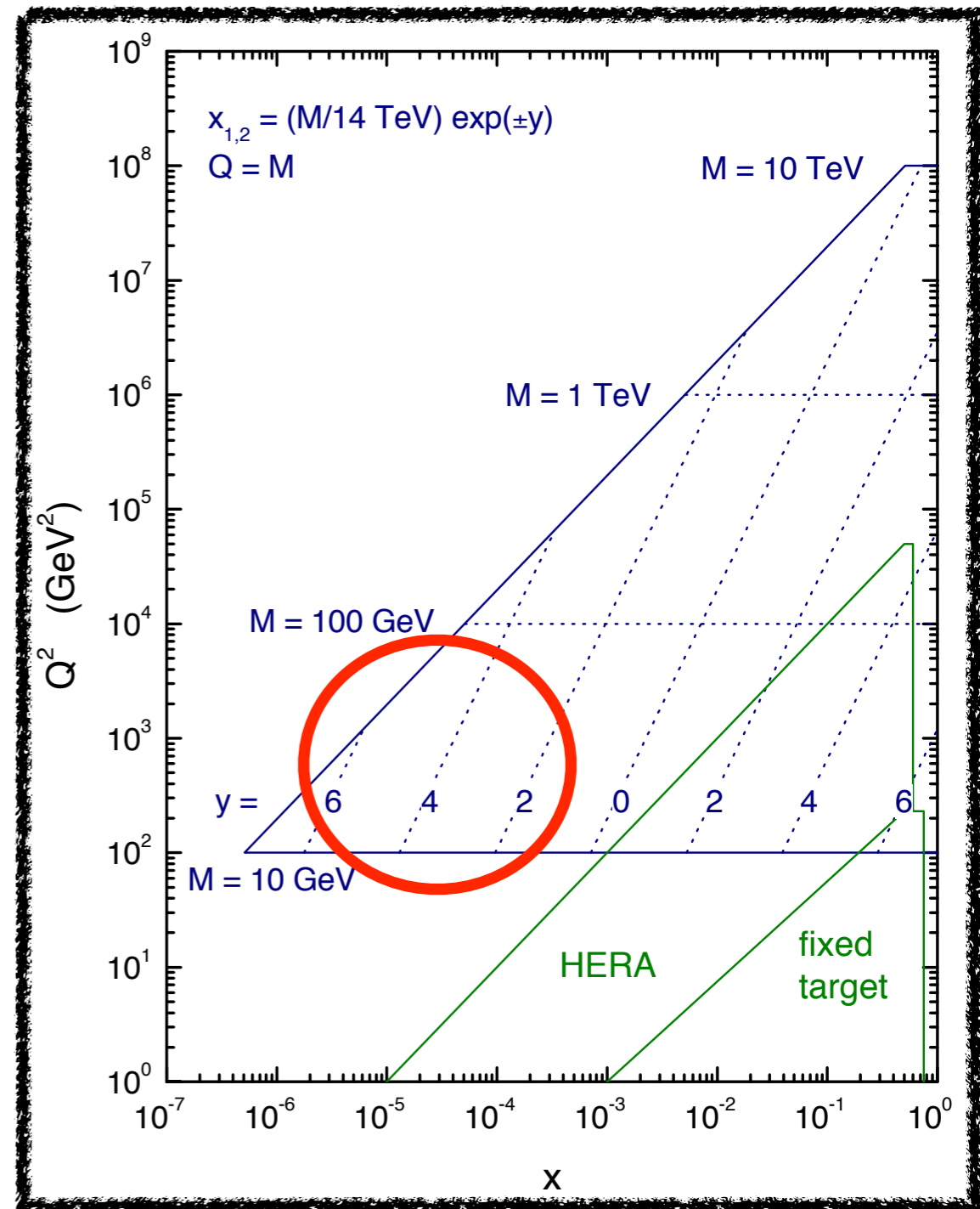
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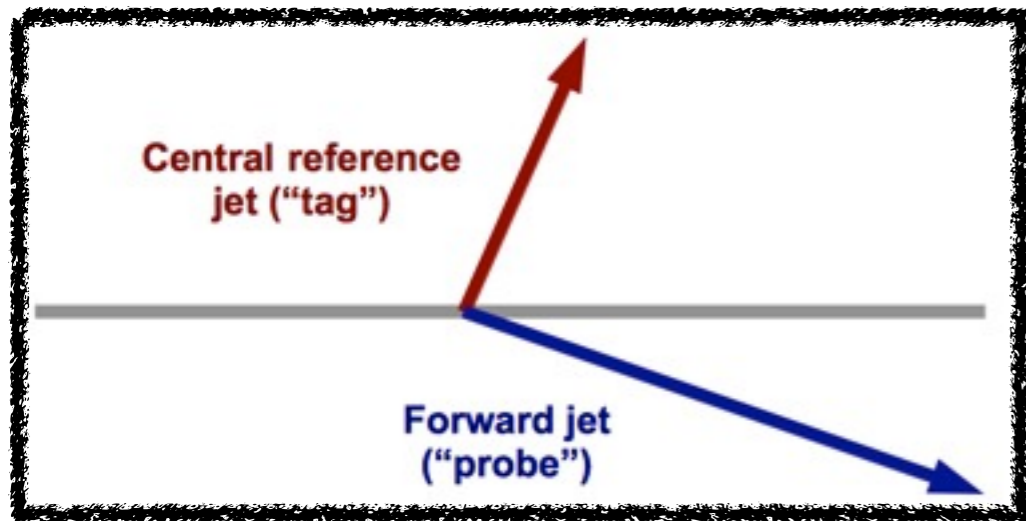
$$\Rightarrow y^* = 0, y_{\text{boost}} = 4.0$$

$$\Rightarrow x_2 \approx 10^{-4} (\sqrt{s} = 7 \text{ TeV})$$



Here, $\sqrt{s} = 14 \text{ TeV}$, and
 $y = (y_1 + y_2)/2 = y_{\text{boost}}$
 $M = Q = 2 p_T \cosh y^*$

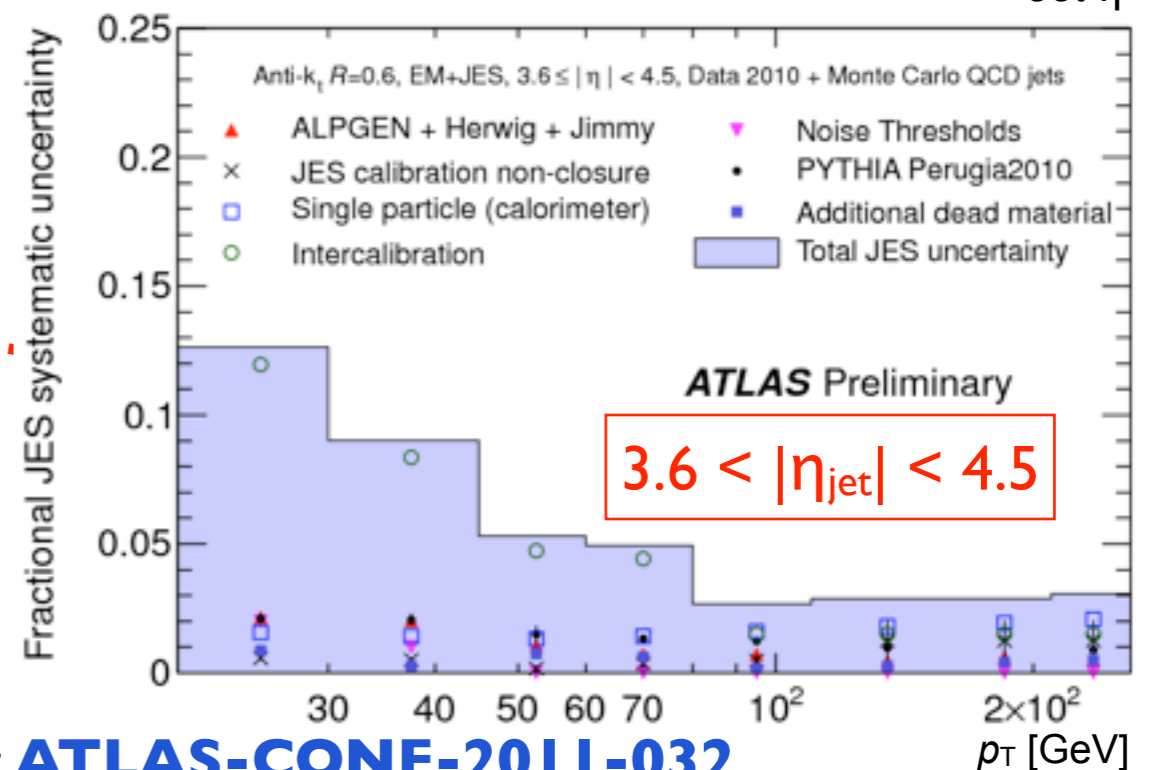
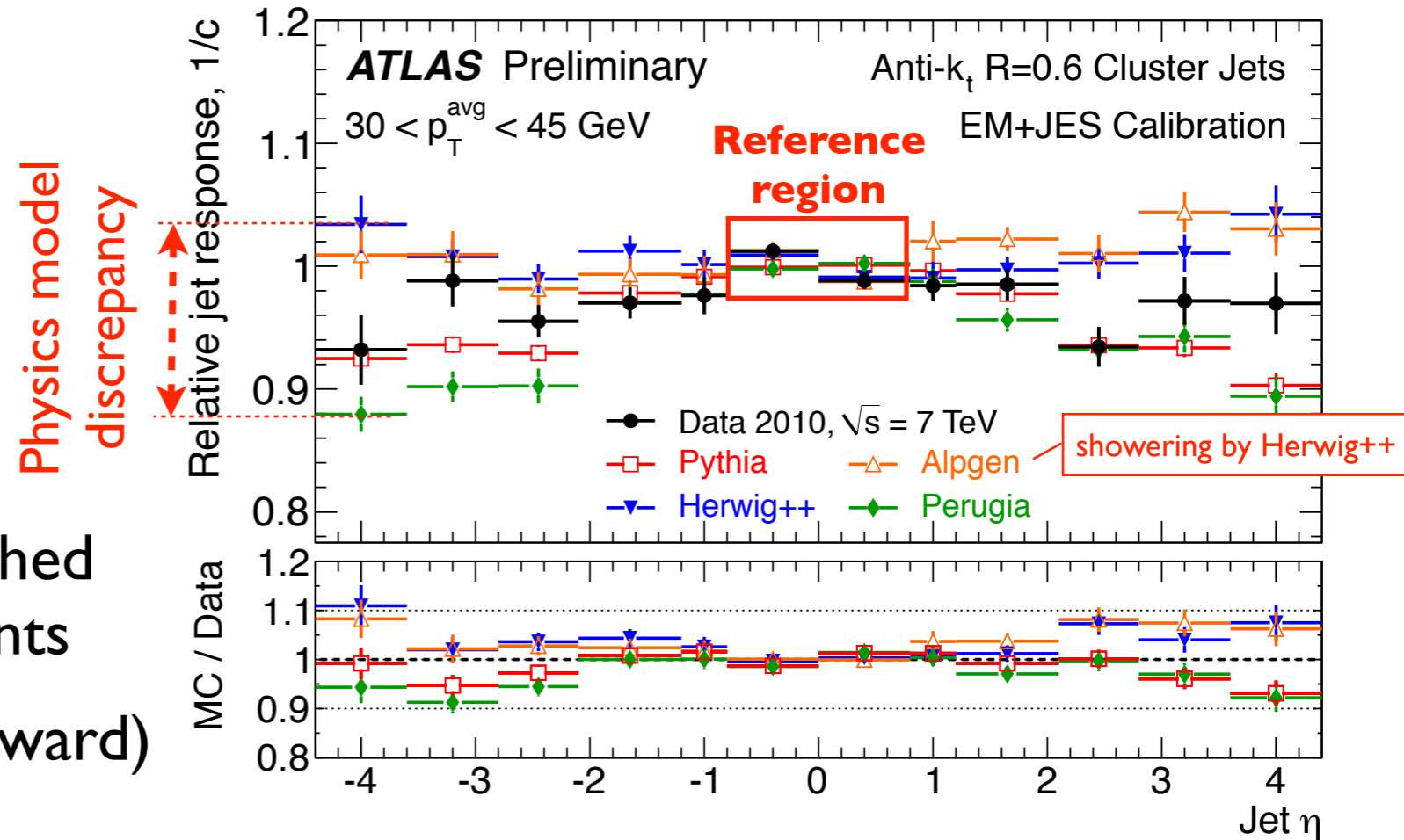
Forward jet calibration



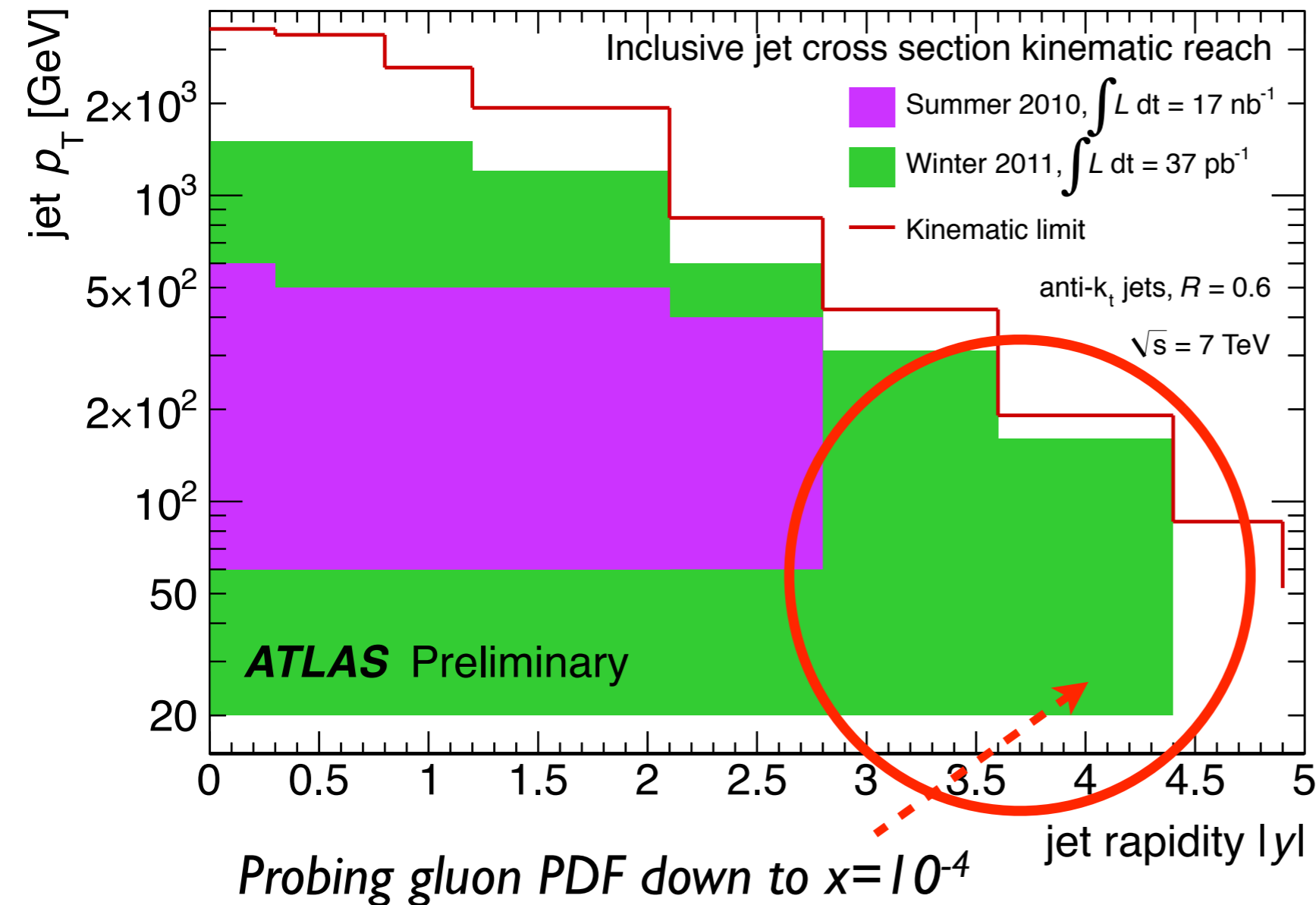
- Forward JES uncertainty established using **p_T balance** of **dijet** events
- Non-perfect balance due to (forward) radiation effects and UE, large **discrepancies** of predictions from **different physics models**
- **Result:** large JES uncertainty for forward jets at low p_T
- Under active investigation ...

Central JES uncert.: **<2.5%** for $60 < p_T < 800$ GeV

Papers: Dijet balance: [ATLAS-CONF-2011-014](#), JES: [ATLAS-CONF-2011-032](#)



Inclusive jet cross section



- Major extension of previous measurement: **low p_T** and **forward y**
- Jet algorithm at ATLAS: Anti k_T , $R=0.4$ and $R=0.6$
- Comparison with prediction from various PDF sets and NLO+PS predictions
- Measured cross section unfolded to particle level
- NLO predictions corrected for non-perturbative effects

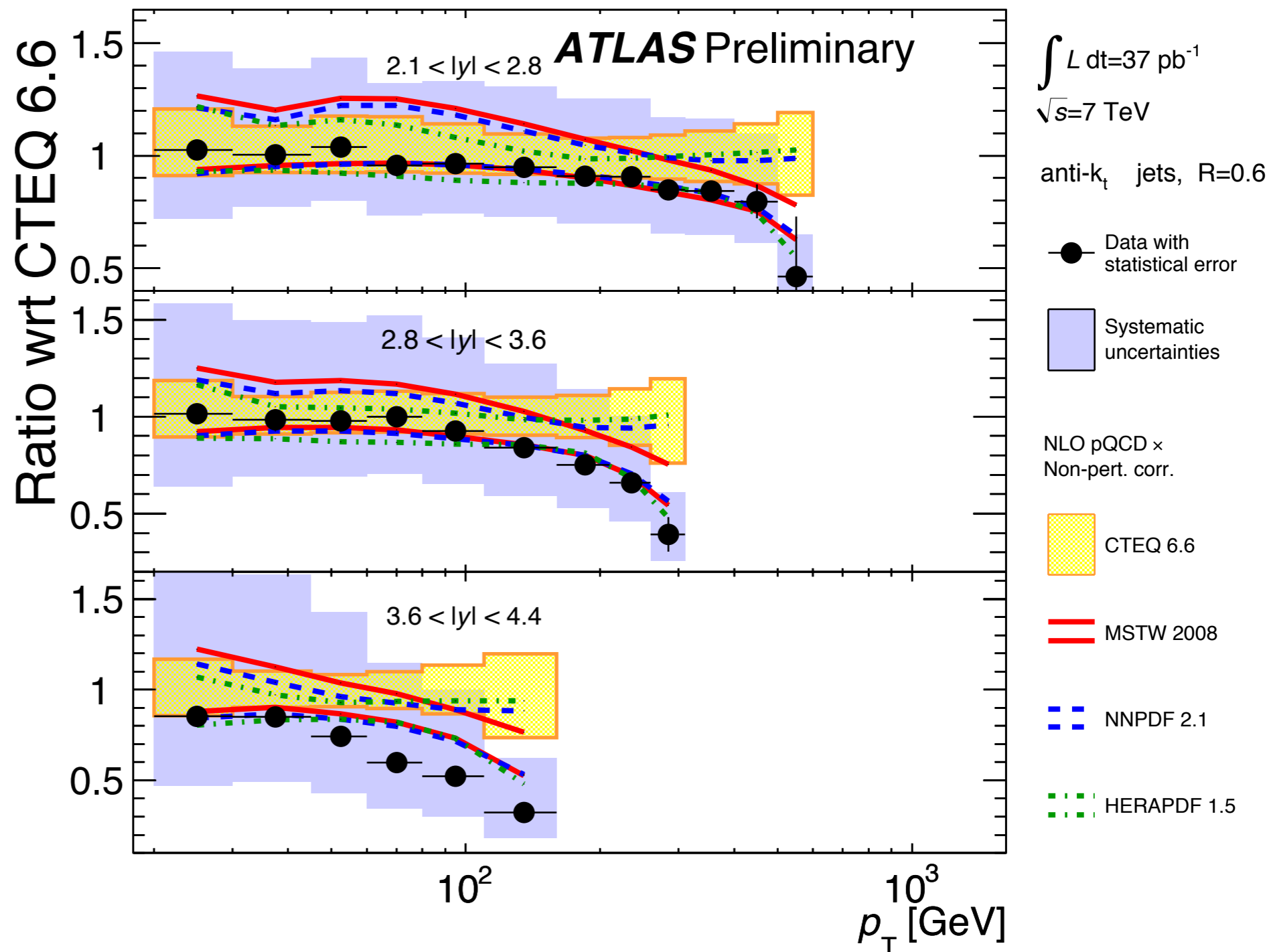
More details about this analysis given in separate talk by Ximo Poveda Torres at this morning's QCD Session

Publication: [ATLAS-CONF-2011-047](#)

Inclusive forward jet cross section

Inclusive jet double-differential cross section:
 $d^2\sigma/(dy dp_T)$

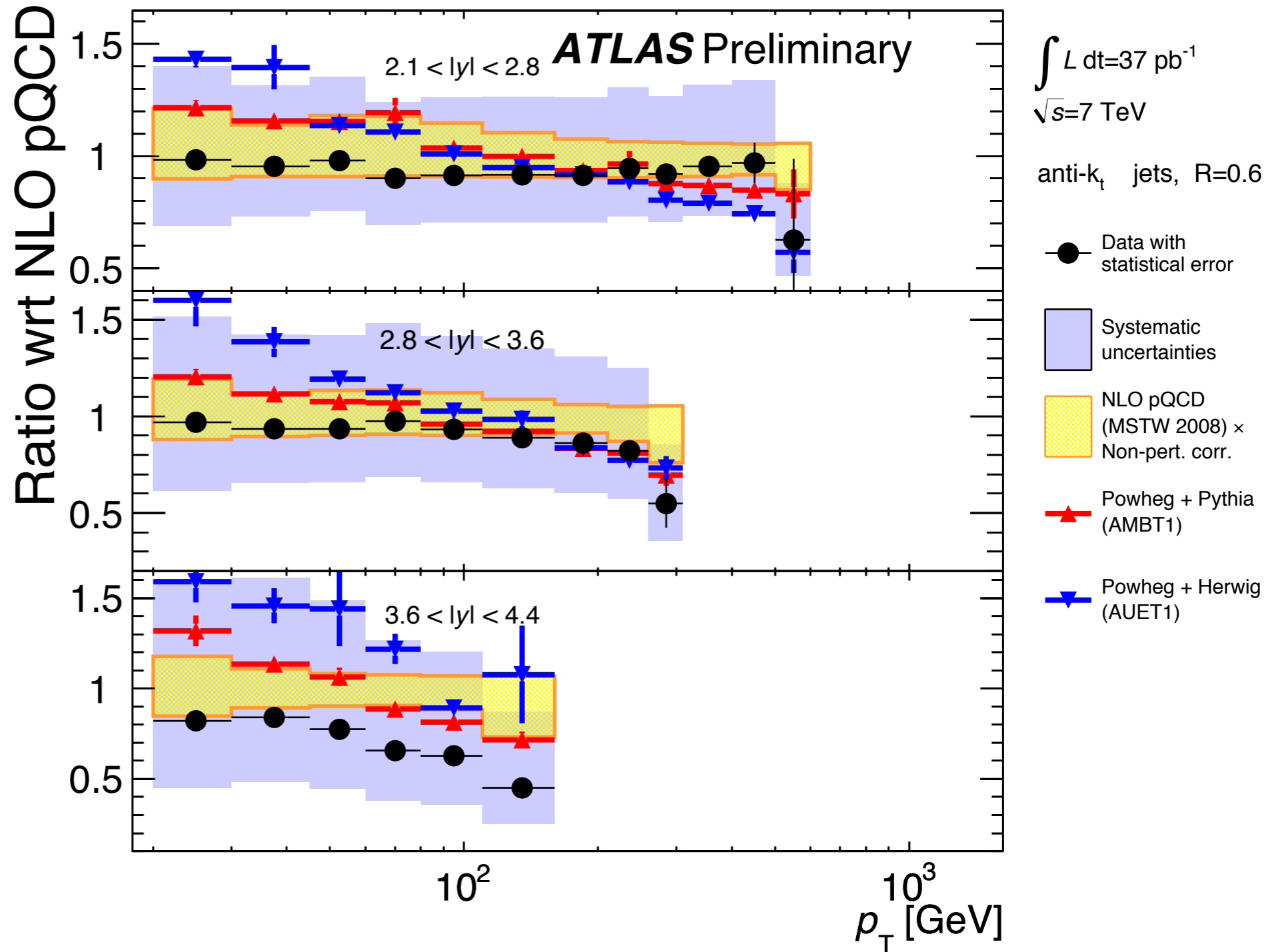
- Data and NLO predictions using different **PDF sets** over CTEQ 6.6 prediction
- NNPDF, HERAPDF 1.5 and in particular MSTW 2008 agree better with data than CTEQ 6.6
- Experimental uncertainty is quite large at low p_T and forward y due to JES



Inclusive jet double-differential cross section as a function of jet p_T in different forward regions of $|y|$ for jets identified using the anti- k_t algorithm with $R = 0.6$.

Inclusive forward jet cross section

- Baseline comparison: Inclusive jet cross section from NLO pQCD
- MSTW2008 PDF set used for all predictions
- The **Powheg NLO** generator is interfaced to **PYTHIA 6** and **HERWIG** for PS and hadronization (first time NLO+PS used for inclusive jets!)
- Discrepancies are being investigated by Powheg authors



The ratio of the Powheg predictions showered using either Pythia or Herwig to the NLO predictions corrected for non-perturbative effects is shown.

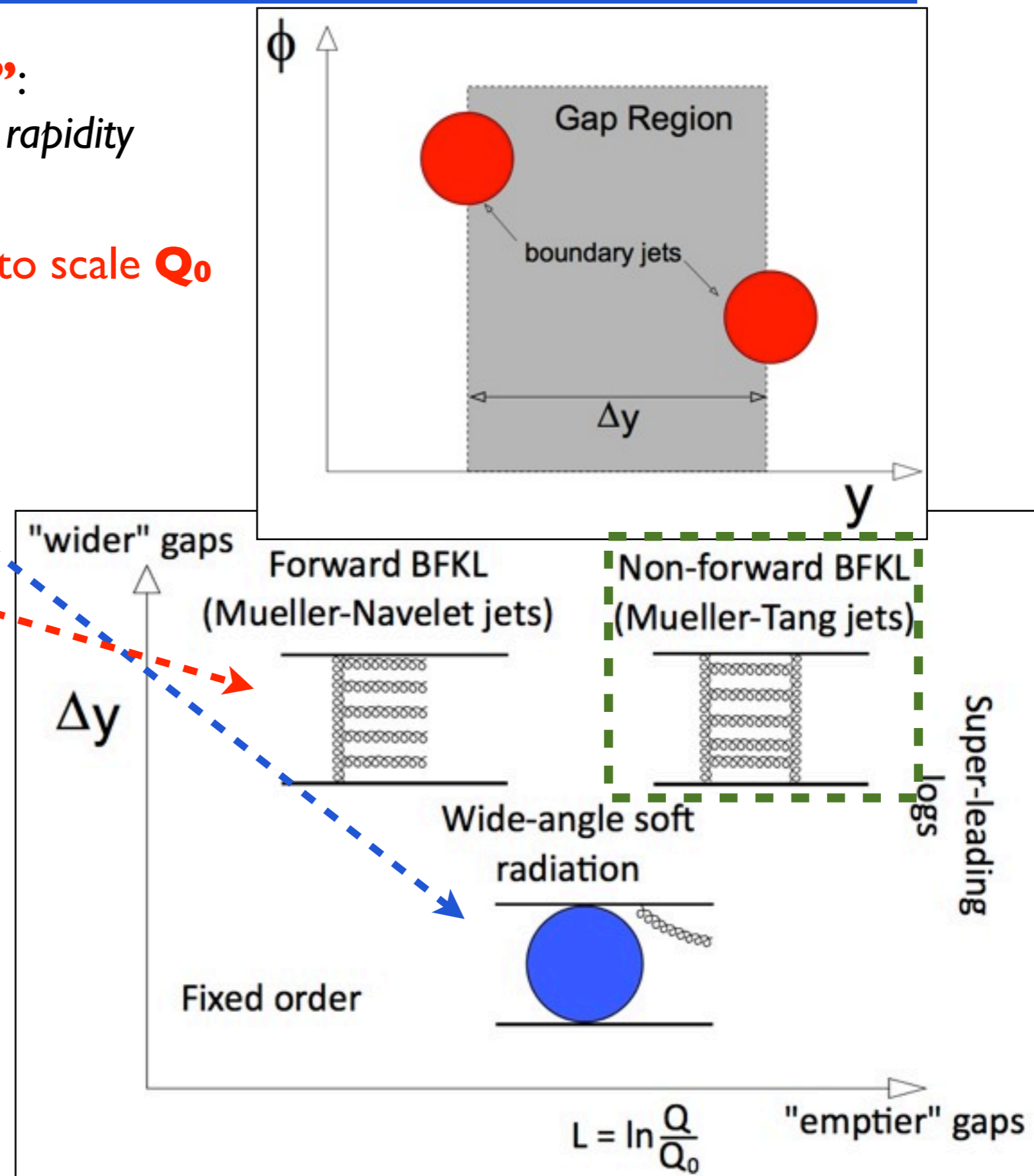
Dijet production with a third jet veto

- Measurement of **“gap fraction”**:
Fraction of dijet events with no jet in rapidity range Δy bounded by dijet system
- No jet in gap with p_T above **jet veto scale Q_0**
- Probe several QCD phenomena:
 - Wide-angle soft-gluon radiation** when **avg. jet $p_T \gg Q_0$**
 - Large Δy separation**
 \Rightarrow potential to test **BFKL**-like dynamics
 - Colour singlet exchange** when events have high p_T and large Δy

Dedicated boundary jet definition to probe scenarios (A) and (B):

(A) **Leading two jets in p_T**

(B) **Most separated in y**



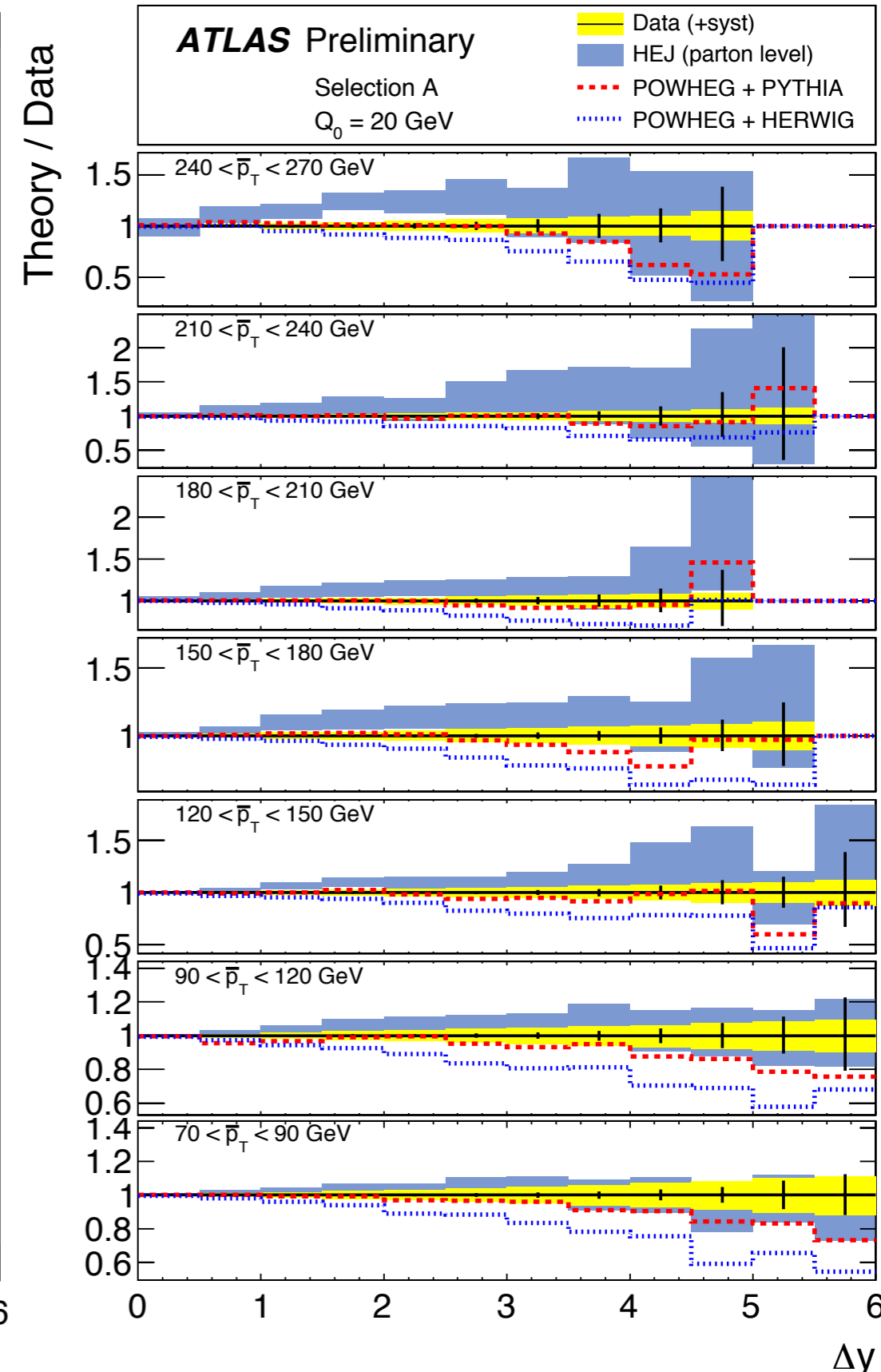
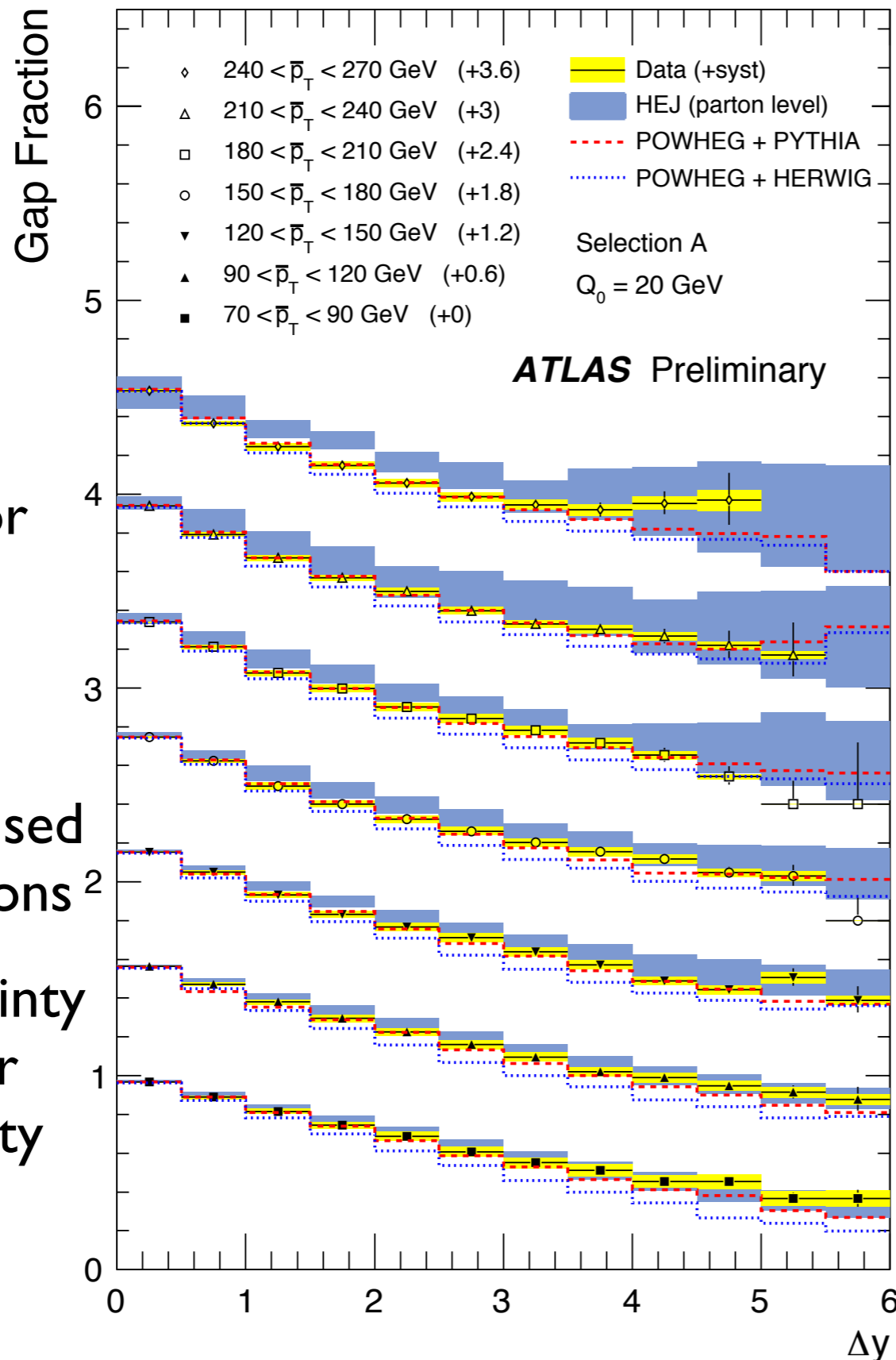
Fraction of events with no jets in gap

HEJ:
Parton-level
MC program
based on a
BFKL kernel

Powheg:
NLO generator
interfaced to
PYTHIA and
HERWIG

MSTW 2008 used
for all predictions

Note: Uncertainty
on data smaller
than uncertainty
on predictions



Number of jets in the rapidity gap region

HEJ:

Parton-level
MC program
based on a
BFKL kernel

Powheg:

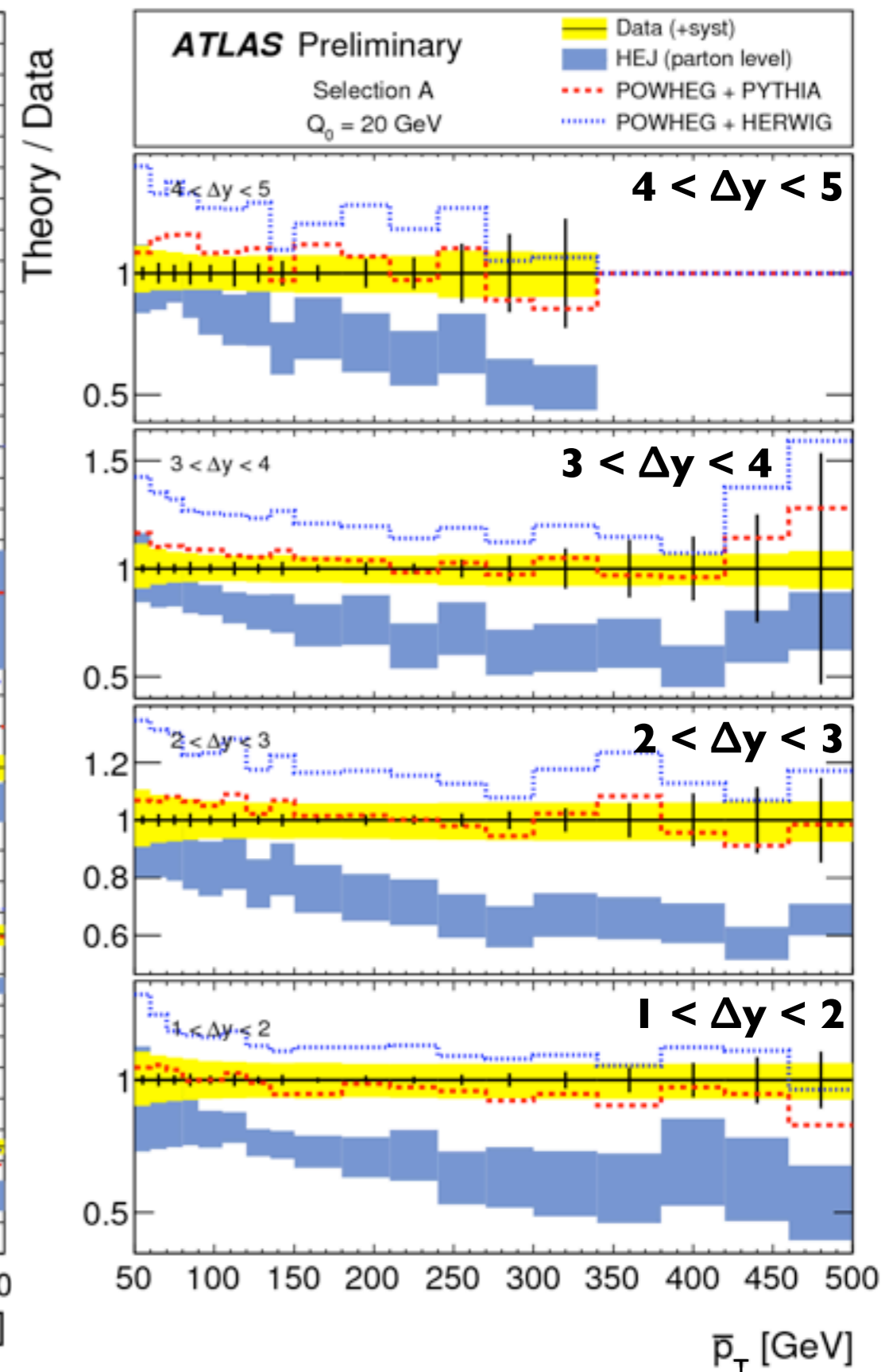
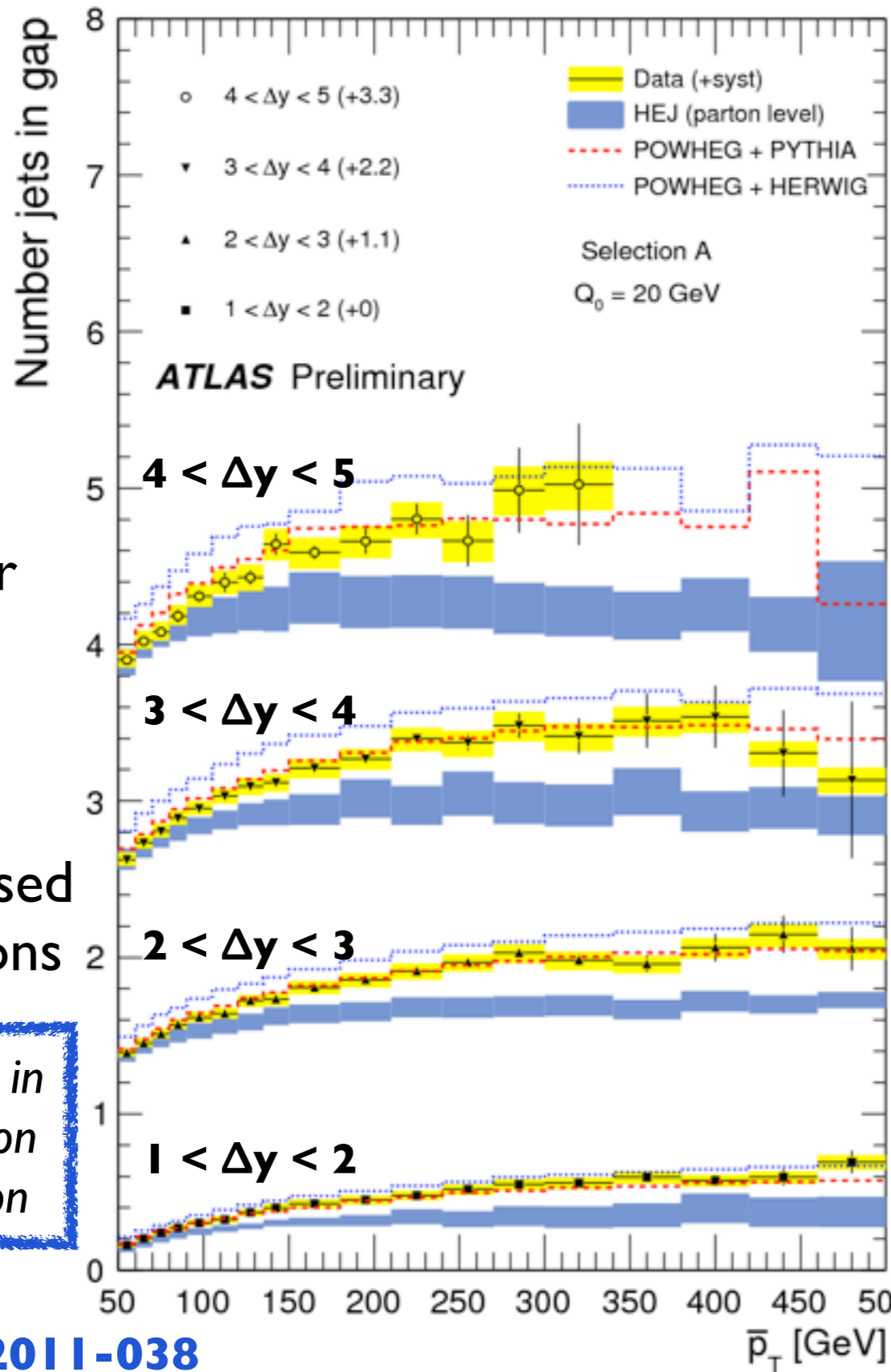
NLO generator
interfaced to
PYTHIA and
HERWIG

MSTW 2008 used
for all predictions

Many more details in
Long Zhao's talk on
Thursday afternoon

Publication:

[ATLAS-CONF-2011-038](#)



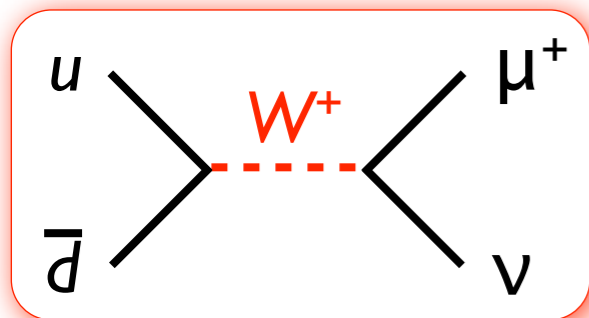
W Charge Asymmetry

- W^+ production larger than W^- at pp colliders due to two u and one d valence quarks

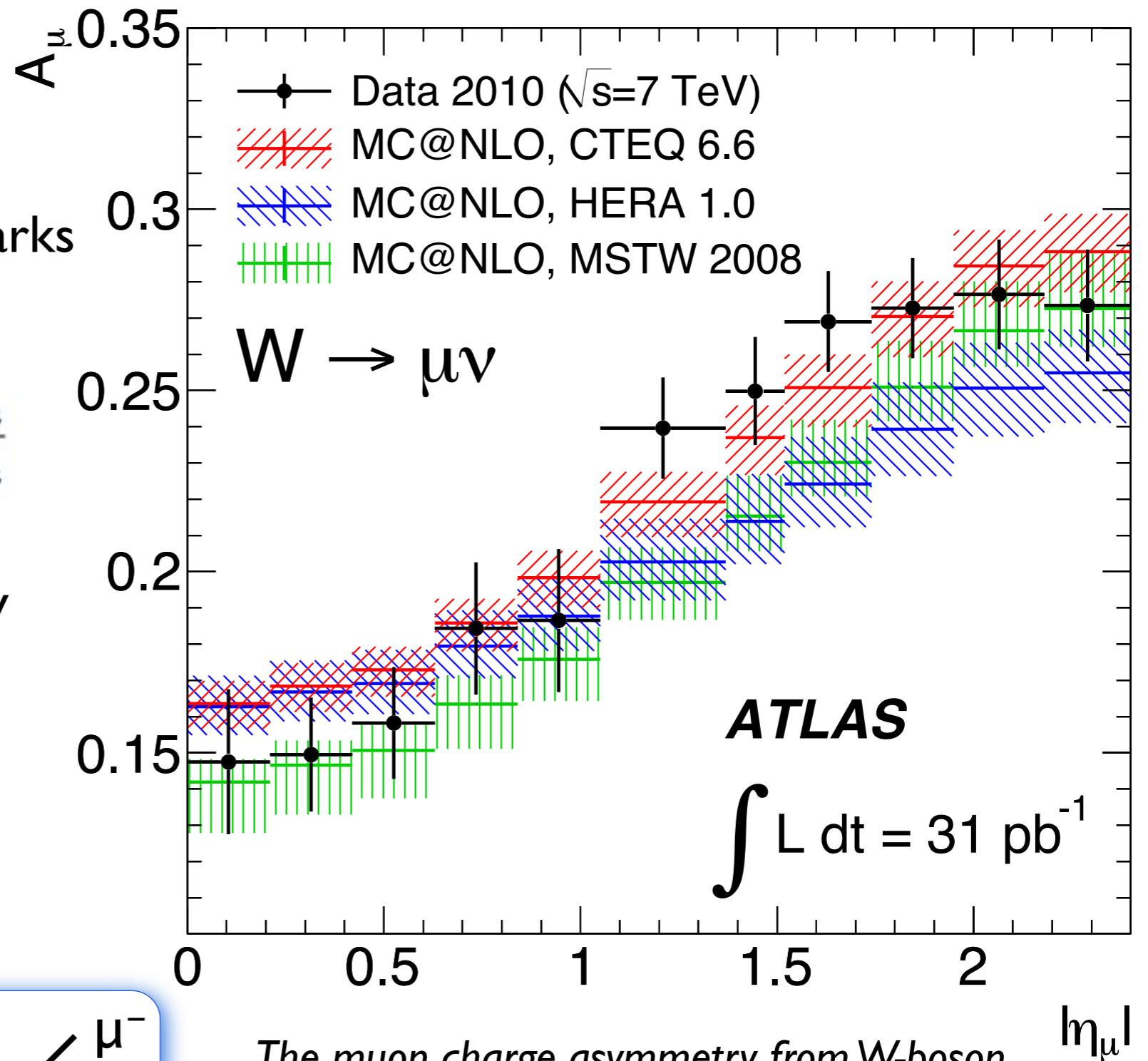
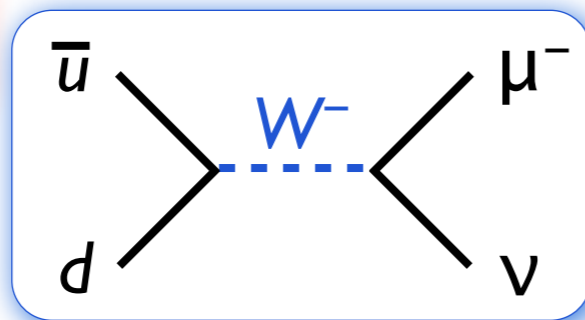
- W charge asymmetry:

$$A_\mu = \frac{d\sigma_{W\mu^+}/d\eta_\mu - d\sigma_{W\mu^-}/d\eta_\mu}{d\sigma_{W\mu^+}/d\eta_\mu + d\sigma_{W\mu^-}/d\eta_\mu}$$

- Can help constrain u and d PDFs approximately for momentum fractions:
 $10^{-3} < x < 10^{-1}$



vs



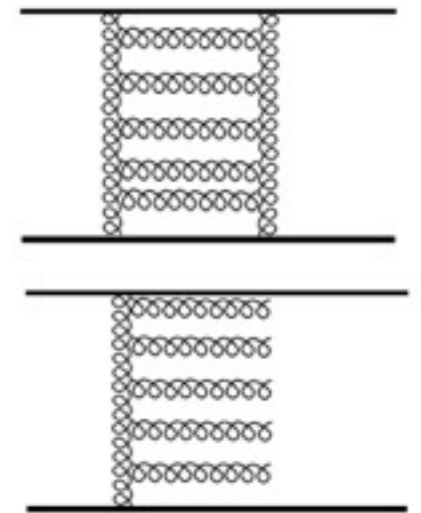
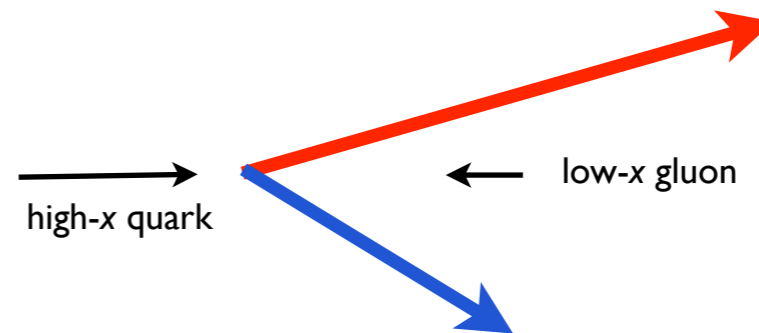
Paper: [arXiv:1103.2929v1](https://arxiv.org/abs/1103.2929v1)



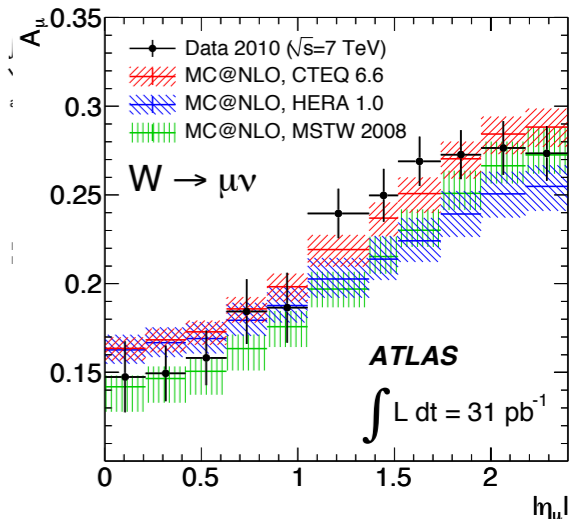
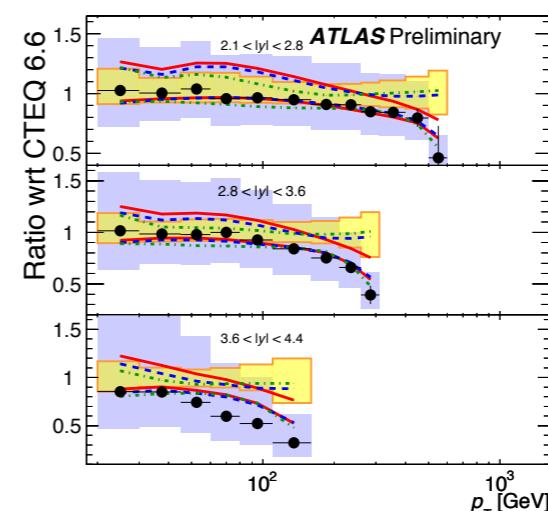
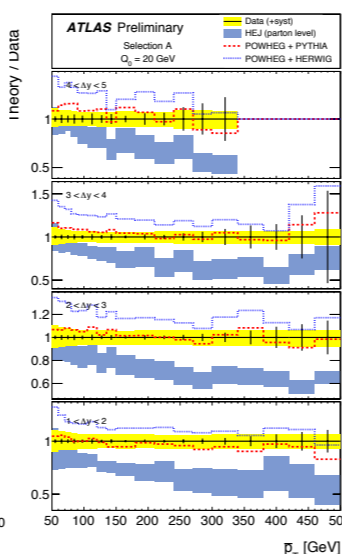
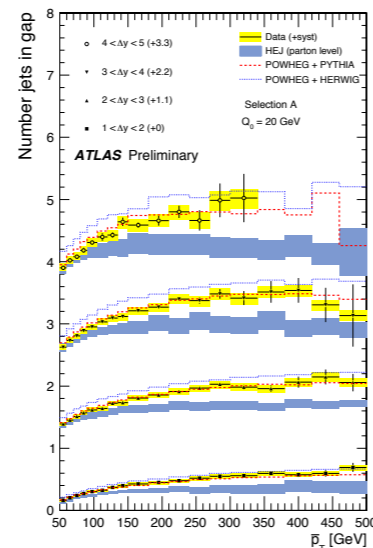
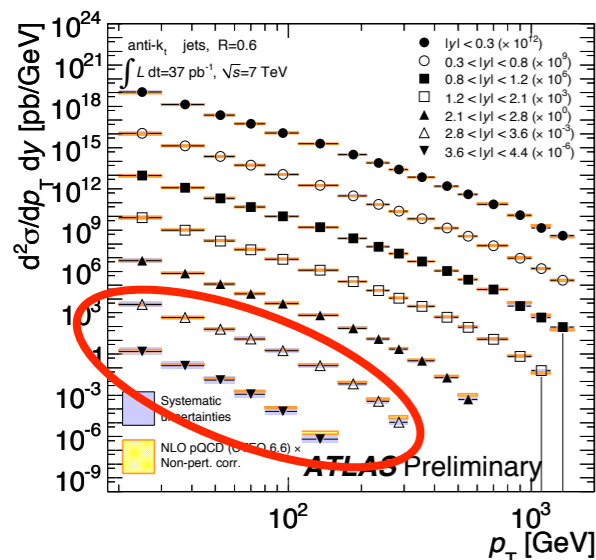
Summary



- The ATLAS detector is working very well and is recording high quality data
- ATLAS has already made several measurements that provide insight to low-x and forward physics
- In this talk results were shown for:
 1. Inclusive forward jet cross section
 2. Rapidity separated dijets events with a third-jet veto
 3. W charge asymmetry
- These measurements, and several more measurement not shown here for brevity, will be used to constrain QCD modelling
- Many more interesting measurements are on-going



STAY TUNED



BACKUP SLIDES

Links to the publications presented

Analyses presented here:

- Dijet balance: [ATLAS-CONF-2011-014](#)
JES uncertainty: [ATLAS-CONF-2011-032](#)
- Inclusive jet cross section: [ATLAS-CONF-2011-047](#)
- Dijet production with a jet veto: [ATLAS-CONF-2011-038](#)
- Muon charge asymmetry from W production: [arXiv:1103.2929v1](#)

A few other low-x analyses:

- Charged particle multiplicity, $\sqrt{s} = 7$ TeV: [ATLAS-CONF-2011-014](#)
Charged particle multiplicity, $\sqrt{s} = 900$ GeV: [CERN-PH-EP-2010-004](#)
- Measurement of the underlying event properties: [arXiv:1103.1816](#)

[ATLAS public Standard Model result page](#)

Forward jet calibration

Goal: Measure eta intercalibration factor **c** (function of jet η and p_T) in dijet events, needed to bring jet to same scale as in the reference region

Central Reference Method (aka Standard Method)

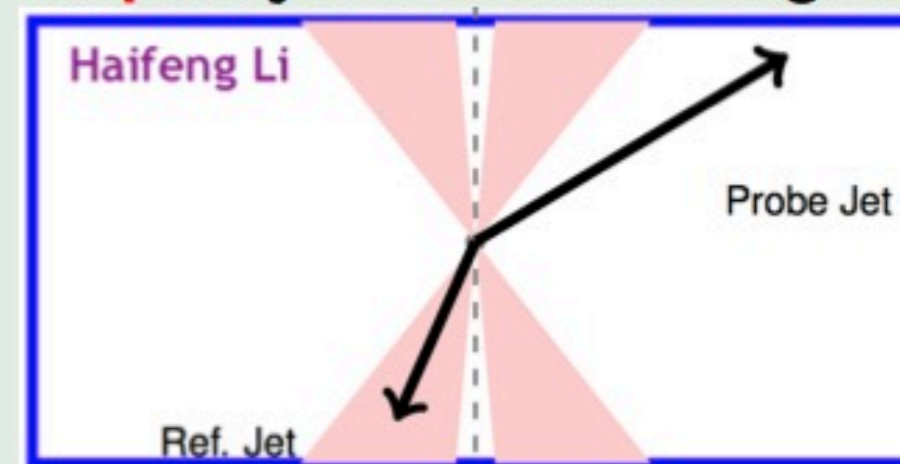
$$p_T^{\text{avg}} = \frac{1}{2}(p_T^{\text{probe}} + p_T^{\text{ref}})$$

$$\mathcal{A} = \frac{p_T^{\text{probe}} - p_T^{\text{ref}}}{p_T^{\text{avg}}},$$

$$\frac{p_T^{\text{probe}}}{p_T^{\text{ref}}} = \frac{2 + \langle \mathcal{A} \rangle}{2 - \langle \mathcal{A} \rangle} = 1/c$$

$$0.1 < |\eta_{\text{ref}}| < 0.6$$

Require jet in **reference** region.

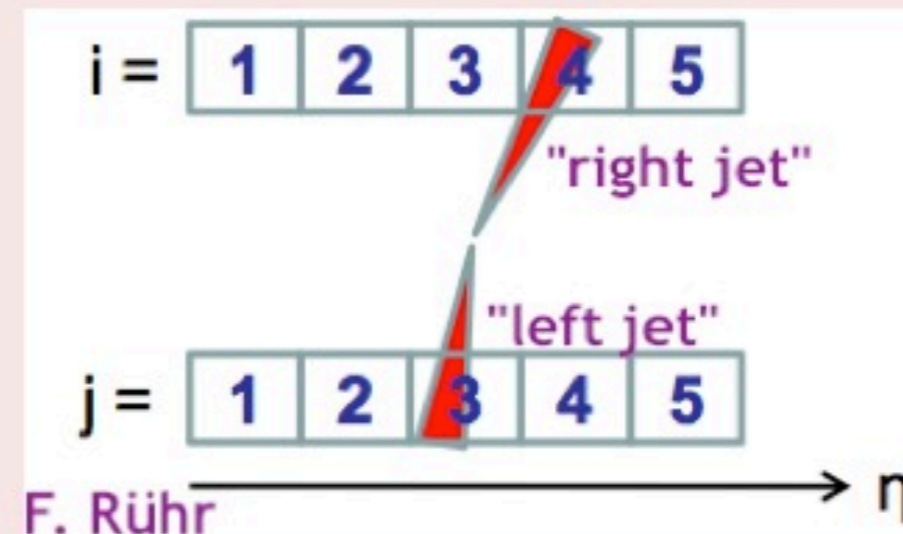


Matrix Method

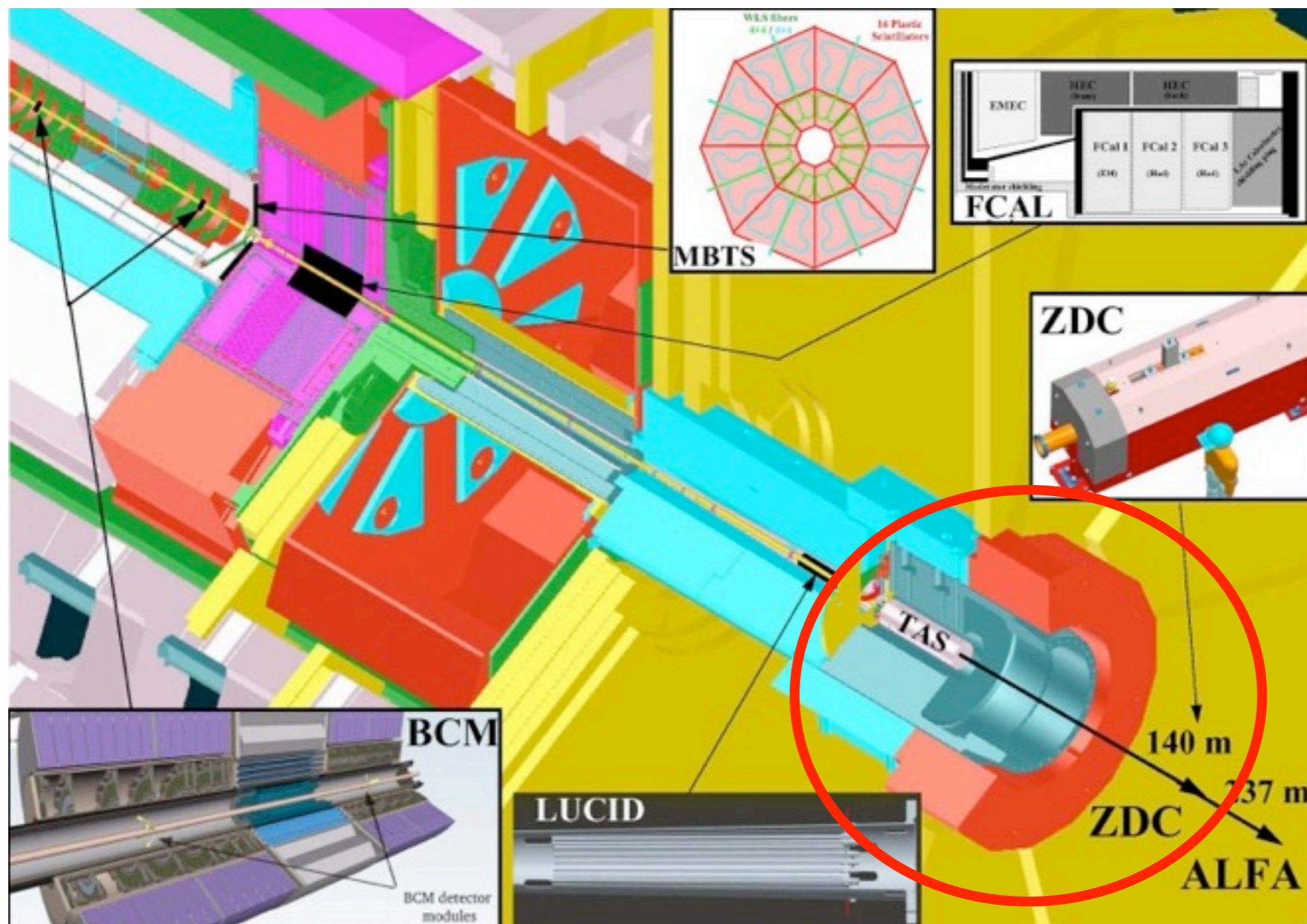
$$\mathcal{A} = \frac{p_T^{\text{left}} - p_T^{\text{right}}}{p_T^{\text{avg}}}, \quad \eta^{\text{left}} < \eta^{\text{right}}$$

$$\mathcal{R} = \frac{p_T^{\text{left}}}{p_T^{\text{right}}} = \frac{c^{\text{right}}}{c^{\text{left}}} = \frac{2 + \langle \mathcal{A} \rangle}{2 - \langle \mathcal{A} \rangle}$$

Solve for all c_i using matrix of lin. eq.



Zero Degree Calorimeter (ZDC)

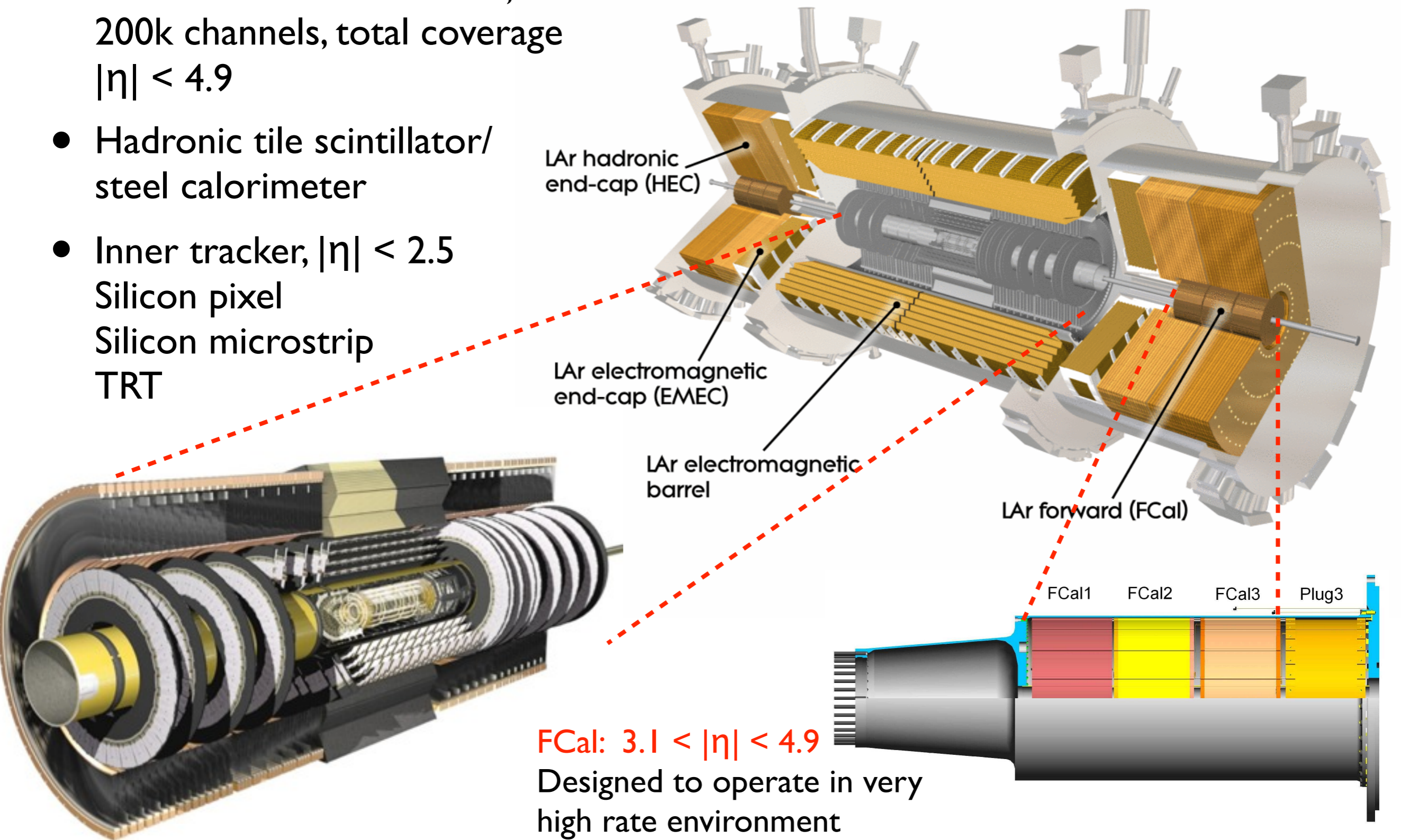


Eta coverage: 8.0-8.6

Potential to access very low $x \sim 10^{-6}$

The ATLAS Calorimeter and Inner Tracker

- Excellent LAr calorimeter, 200k channels, total coverage $|\eta| < 4.9$
- Hadronic tile scintillator/steel calorimeter
- Inner tracker, $|\eta| < 2.5$
Silicon pixel
Silicon microstrip
TRT



Dijet production with a third jet veto

HEJ:
Parton-level
MC program
based on a
BFKL kernel

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MSTW 2008 used
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Note: Uncertainty
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